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The goal of the proposed research was to understand the means by which XUV radiation in solar flares is excited, and to use this radiation as diagnostics of the energy release and transport processes occurring in the flare. The work was carried out by A. G. Emslie, T. N. LaRosa, and graduate student P. Li. We have made significant progress in both of these areas, as described below.

(1) Chromospheric Heating and Soft X-ray Line Profiles

Soft X-ray-emitting plasma is believed to be produced when energy is deposited in the cool chromospheric layers of the flare atmosphere, resulting in a dramatic rise in temperature up to $T \sim 10^7\text{K}$. Concomitant with this temperature rise should be the formation of a region of high pressure, which should in turn drive upflows into the low-pressure overlying corona. This process, referred to as "chromospheric evaporation", should manifest itself through a blueshift in the profiles of spectral lines formed in the hot material. Observations, however (e.g. Antonucci et al 1982; McClements and Alexander 1989) show a line profile with a principal component at the laboratory rest wavelength of the line. In order to better understand this discrepancy between theory and observation, we carried out a series of hydrodynamic simulations of electron-heated model atmospheres (Mariska et al 1989; Li et al 1989, Emslie et al 1992). Our conclusions are that only if the preflare atmosphere is significantly preheated and if the magnetic field strength in the

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N94-24094

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flare loop is fairly uniform can a single loop model be made consistent with the observations.

We also calculated the ratio of primary (i.e. direct beam) bremsstrahlung to secondary bremsstrahlung (i.e. that produced from the hot plasma energized by the electron beam). Our results (Li and Emslie 1989) show that emission can be dominated by the secondary bremsstrahlung below quite substantial energies (up to ~ 30 keV in some cases). Consequently, previous interpretation of hard X-ray signatures at modest energies as purely primary bremsstrahlung is open to question; observations at energies well above 20–30 keV are needed to examine the nonthermal component in isolation. This work constituted the bulk of Mr. P. Li's Ph.D. dissertation research.

(2) Electron Acceleration and Dynamics

XUV plasma is produced by collisional heating of energetic electrons. Yet the mechanism for production of these electrons is far from clear. A process frequently invoked is Dreicer runaway in the presence of a large direct electric field. In emerging flux models of flares (e.g. Heyvaerts *et al* 1976), this electric field results from annihilation of magnetic field ($\nabla \times \mathbf{E} = -c^{-1} \partial \mathbf{B} / \partial t$) in the interaction region between two loop structures. Overlooked in the analysis, however, is that the rate of change of B depends on the resistivity η (through the magnetic diffusion equation), and that while high values of η enhance the reconnection rate ($\partial B / \partial t$) and hence the electric field strength, the collisional drag on the electrons is also proportional to η . This implies that runaway acceleration is only possible in a driven system where the reconnection speed v is imposed by external means and large ($\nabla \times \mathbf{B}$) electric fields can be generated without an increase in resistivity. These, and other, facets of the emerging flux model have been examined by LaRosa (1992), who concludes that the model in its present form is inadequate to explain large impulsive events.

The mechanism for establishing beam-neutralizing return currents (which can produce XUV plasma through Ohmic heating) was investigated by LaRosa and Emslie

(1989). They concluded that the electrostatic (charge separation) electric field dominates over the inductive electric field at most times and locations in the flare.

(3) Correlations of Hard X-Ray and EUV Bursts

There is a well-established correlation between hard X-ray and EUV intensities in flares (e.g. McClymont and Canfield 1986). It has been shown by Emslie *et al* (1978) and McClymont and Canfield (1986) that this correlation is naturally explained if the EUV radiation is produced through collisional heating by a power-law flux of non-thermal electrons; however, the required area of injection is very small ($\leq 10^{17} \text{ cm}^2$). We have argued (LaRosa and Emslie 1988) that such a small injection area is untenable in large events, due to the unphysically huge fluxes it implies. This in turn means that the magnetic field must be tapered, in order that the electrons are injected over a much larger area than that of the EUV-emitting chromospheric footpoint. (By the time the electrons reach the footpoint, their flux has been reduced to an acceptable level through collisional attenuation.) This result is especially significant in light of conclusions of our soft X-ray line profile study (Section (1)), which sets an upper limit on the magnetic field tapering factor. Work on reconciling these two results is in progress.

Summary

The SMM-era data, particularly in the XUV domain, has been very valuable in constraining our ideas about energy release and transport in flares. We look forward to an extension of these ideas into the new-generation observations promised by the High-Energy Solar Physics (HESP) mission.

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